DC-1

SEM-2

PAPER-IV: Fundamentals of Biochemistry

Lesson: Lipids

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Chapter: Lipids

Introduction

Lipids are a class of biological molecules defined by low solubility in water and high solubility in nonpolar solvents such as ether and chloroform. As molecules that are largely hydrocarbon in nature, lipids represent highly reduced forms of carbon and upon oxidation, yield enormous amount of energy. They are therefore the molecules for metabolic energy storage.

The lipids found in biological systems possess both polar and nonpolar groups and are thus either **hydrophobic** (containing only nonpolar groups) or **amphipathic,** possessing both polar and non-polar groups. The biological membranes act as effective barriers to more polar molecules because of hydrophobic nature of lipid molecules. Fat is stored in adipose tissue where it also serves as a thermal insulator in subcutaneous tissue and around certain organs.

Biological Roles

Lipids have a highly diverse chemistry and biological functions. Following are some of their main biological functions:

- Energy storage. Yield enormous amount of energy on oxidation during metabolism.
- Fats and oils are the principal stored forms of energy in most of the organisms. As compared to carbohydrates they can be stored easily. On oxidation they yield enormous amount of energy during metabolism.
- Certain essential fatty acids are provided by lipids which otherwise cannot be synthesized by the body.
- Fat soluble vitamins like A, D, E, and K are provided by lipids to the body.
- Lipids are important constituents of the biological membranes and as they are hydrophobic in nature, act as barriers to polar molecules like water. Biological membranes are made up of Phospholipids and sterols so lipids have a structural role in addition to the storage.
- They also have a role as cofactor, hormones, electron transport carriers, light absorbing pigments and hydrophobic anchors for proteins.
- They act like Chaperones and help membrane proteins to fold.
- They act like emulsifying agents and can form micelles in the digestive tract.

- Membrane lipids play an important role in signal transduction as they form precursors for second messengers e.g. Eicosanoids, sphingolipids and glycerophospholipids.
- Lipids act as insulators in higher animals as they are found in subcutaneous tissue and around certain organs.

Video: What are lipids

Source:[**http://www.thevisualmd.com/read_videoguide/?idu=1083610266&p=9**](http://www.thevisualmd.com/read_videoguide/?idu=1083610266&p=9)

Video: Lipids

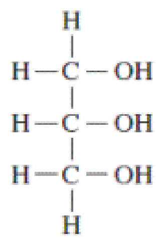
Source: [**http://media-2.web.britannica.com/eb-media/42/86842-024-B8D8F6A3.mp4**](http://media-2.web.britannica.com/eb-media/42/86842-024-B8D8F6A3.mp4)

Types of Lipids

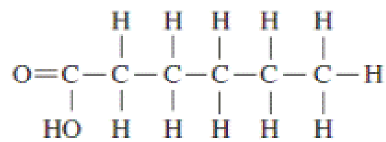
Lipids are broadly classified as simple lipids and complex lipids:

1. **Simple Lipids:** They are the esters of fatty acids with alcohols.

(a) **Fats and Oils** are esters of fatty acids with glycerol. Glycerol is an alcohol with three carbons each having a hydroxyl group and fatty acid is a long carbon chain with 16-18 carbon atoms having carboxyl group as a functional group at one end.



Glycerol



Fatty acid

The hydrophobic nature of fats is due to the nonpolar C-H bonds in the hydrocarbon chains of fatty acids. Each molecule of fat has three fatty acids and one glycerol. By definition fats are solid and oils are liquid at room temperature. Butter and ghee are animal fats rich in saturated fats whereas plant oils have more of unsaturated fats.

(b) **Waxes** are esters of fatty acids with high molecular weight alcohols.

2. **Complex Lipids:** Like simple lipids they are also the esters of fatty acids and alcohols but contain groups besides fatty acid and glycerol. They are further classified into three sub groups depending upon the additional group they have:

(a) **Phospholipids** are amphipathic membrane lipids where a polar head is linked to nonpolar tail by a **phosphodiester linkage**. In **Glycerophospholipids** the alcohol is glycerol whereas it is sphingosine in **Sphingophospholipids.**

(b) **Glycolipids** have a carbohydrate moiety attached to the fatty acid and alcohol**.**

(c) **Other Complex Lipids:** Lipids such as sulpholipids, amino lipids and lipoproteins come under this group of lipids.

3. **Precursor and Derived Lipids:** They are the hydrolytic products of simple and compound lipids e.g. hydrocarbons, fatty acids, glycerol and other alcohols, lipid soluble vitamins and hormones and steroids.

According to their biological function lipids can also be classified broadly into two categories:

- **Structural lipids**: They are present in the biological membranes. These include glycerophosppholipids, galactolipids, sulpholipids, sphingolipids and cholesterol. They vary in their structure, but all have a polar and nonpolar constituent in them.

❖ **Storage lipids**: Fats and oils (Triacylglycerol) belongs to the storage lipids. They act as a universal source of biological fuel. In some species such as plankton they serves as the chief storage form of biological fuel.

Fatty Acids

Fatty acids are the building blocks of lipids. A fatty acid is made up of two parts: a long hydrocarbon chain (tail) and a terminal head formed by a carboxyl group (head).

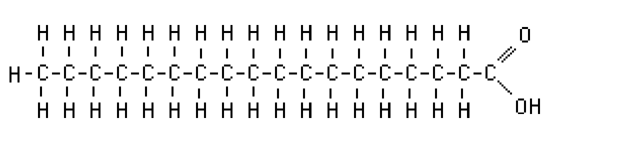


Figure: Structure of a typical fatty acid

Fatty acids vary in the length and degree of unsaturation. They rarely occur in free form (arachidonic acid being an exception) and are esterified to glycerol or other molecules to form fats or other lipids.

Fatty acids are of two types:

- **Saturated fatty acids** have single bonds in their hydrocarbon chain.

Saturated Fatty Acids		
Formula	**Common Name**	**Melting Point**
$CH_3(CH_2)_{10}CO_2H$	lauric acid	45 °C
$CH_3(CH_2)_{12}CO_2H$	myristic acid	55 °C
$CH_3(CH_2)_{14}CO_2H$	palmitic acid	63 °C
$CH_3(CH_2)_{16}CO_2H$	stearic acid	69 °C
$CH_3(CH_2)_{18}CO_2H$	arachidic acid	76 °C

Source:http://chemwiki.ucdavis.edu/Organic_Chemistry/Lipids/Fatty_Acids

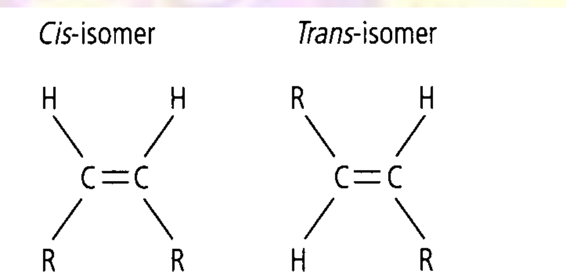
- **Unsaturated fatty acids** have one or more double bonds in their structure.

Unsaturated Fatty Acids		
Formula	Common Name	Melting Point
$CH_3(CH_2)_5CH=CH(CH_2)_7CO_2H$	palmitoleic acid	0 °C
$CH_3(CH_2)_7CH=CH(CH_2)_7CO_2H$	oleic acid	13 °C
$CH_3(CH_2)_4CH=CHCH_2CH=CH(CH_2)_7CO_2H$	linoleic acid	-5 °C
$CH_3CH_2CH=CHCH_2CH=CHCH_2CH=CH(CH_2)_7CO_2H$	linolenic acid	-11 °C
$CH_3(CH_2)_4(CH=CHCH_2)_4(CH_2)_2CO_2H$	arachidonic acid	-49 °C

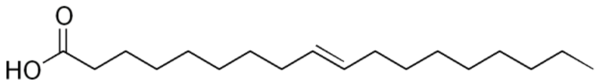
Source:http://chemwiki.ucdavis.edu/Organic_Chemistry/Lipids/Fatty_Acids

Saturated fatty acid chains are packed closely forming rigid structures but unsaturated fatty acids produce flexible structures in the form of fluid aggregates. The reason for this is a kind of geometric isomerism that occurs in unsaturated fatty acids and depends on the orientation of atoms or groups around the axes of double bonds.

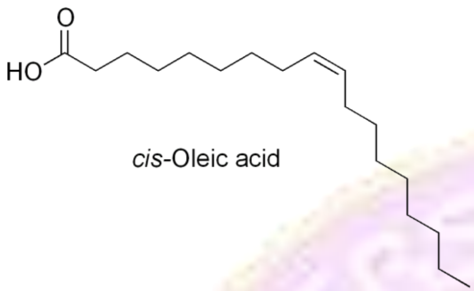
If the acryl chains are on the same side of double bond, it is cis- fatty acid and if on opposite side it is trans-fatty acid. All naturally occurring unsaturated fatty acids have cis-configuration. Trans fatty acids are produced as a byproduct during hydrogenation of fatty acids or hardening of natural oils.



In the cis fatty acids there is a bent or kink at 120° at the double bond. The trans fatty acids appear straight and tend to pack in a orderly way (form solid phase) unlike the cis fatty acids that are bent (with kinks) and therefore do not stack (therefore occur as liquids). Cis fatty acids thus have a lower melting points than trans or saturated fatty acids.



trans-Oleic acid



cis-Oleic acid

Source: http://en.wikipedia.org/wiki/Fatty_acid

As the number of double bonds increases, variety of spatial configurations of the molecules also increases. e.g. Arachidonic acid has four double bonds, therefore it is U- shaped. To summarize, the properties of fatty acids is dependent on the degree of unsaturation and chain length. The shorter the chain length or higher the degree of unsaturation the lower the melting point.

In higher plants, unsaturated fatty acids are more abundant than saturated fatty acids.

Nomenclature

The names of the fatty acids are based on their parent hydrocarbon with –*oic* replaced by –*e*. So saturated fatty acids end in –*anoic* and unsaturated end in –*enoic*.

For example:

Parent 18 C hydrocarbon- Octadecane

C_{18} saturated fatty acid- Octadec*anoic* acid

C_{18} unsaturated fatty acid with a single double bond- Octadec*enoic* acid

C_{18} unsaturated fatty acid with a two double bond - Octa*dienoic* acid

Carbon atoms in the fatty acids are numbered starting from the carboxyl terminus. Carboxyl carbon is numbered 1, 2^{nd} and 3^{rd} carbons are named as α and β respectively. The terminal methyl carbon is named as ω carbon. Δ indicates the number and position of double bonds e.g. Δ^9 means double bond is between C9 and 10 of fatty acid. Alternatively the counting can be done from the distal side with the ω carbon as number 1 for e.g. ω^9 means a double bond is on ninth carbon from ω-carbon.

Structural Lipids-Membrane Lipids

Biological membranes are composed of a lipid bilayer, which is hydrophobic in nature and thus does not allow polar molecules and ions to enter the membrane. Membrane lipids are amphipathic having polar head (hydrophilic) and non-polar tail (hydrophobic). Hydrophilic interactions with water and hydrophobic interactions with each other pack these molecules into membrane bilayers.

There are three main types of membrane lipids:

- Phospholipids
- Glycolipids
- Cholesterol

1.**Phospholipids**

Phospholipids are the major class of membrane lipids as they form lipid bilayers. Phospholipids as the name suggests are phosphate containing lipids, having hydrophobic moieties joined through a phosphodiester linkage to polar head groups. Glycerophospholipids and Sphingolipids are the two major categories of phospholipids. Phospholipids built on glycerol are known as **Glycerophospholipids** or phosphoglycerides. Two fatty acids are joined through an ester linkage to 1st and 2nd carbon of glycerol and the 3rd carbon has a highly charged polar group (generally an alcohol) linked through a phosphodiester bond. The simplest glycerophospholipid is phosphatidic acid where C-3 of glycerol is esterified to phosphoric acid or X (polar head group) is H (figure: glycerophospholipids). Based on the alcohol bound to the phosphate group on glycerol backbone these glycerophospholipids are named e.g., phosphatidylcholine and phosphatidylethanolamine have choline and ethanolamine as their polar head groups or X. Other examples are given in Table 1.

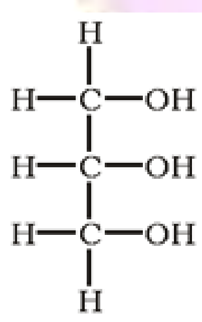


Figure: Structure of glycerol

Source: http://apchemcyhs.wikispaces.com/file/view/glycerol2.png/141456527/275x200/glycerol2.png

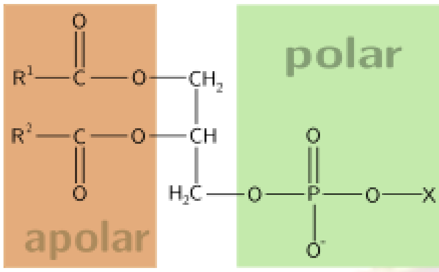


Figure: Glycerophospholipids

Source: http://upload.wikimedia.org/wikipedia/commons/thumb/f/fd/Phospholipid.svg/220px-Phospholipid.svg.png

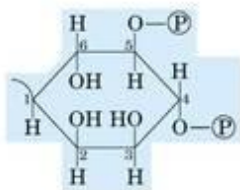
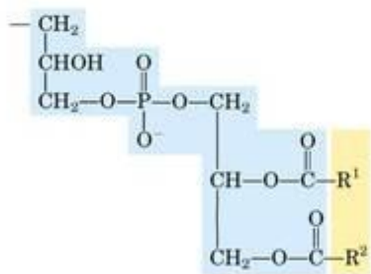
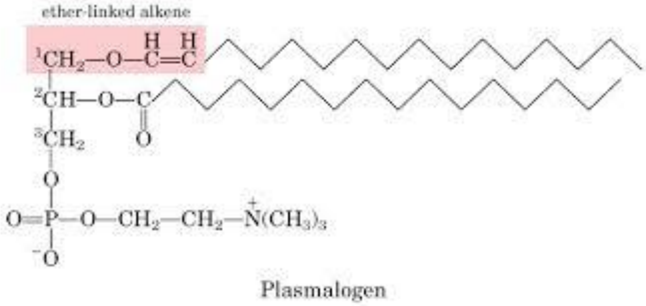
Name of glycerophospholipid	Name of X	Formula of X	Net charge (at pH 7)
Phosphatidic acid	—	$-H$	−1
Phosphatidylethanolamine	Ethanolamine	$-CH_2-CH_2-\overset{+}{N}H_3$	0
Phosphatidylcholine	Choline	$-CH_2-CH_2-\overset{+}{N}(CH_3)_3$	0
Phosphatidylserine	Serine	$-CH_2-CH(COO^-)-\overset{+}{N}H_3$	−1
Phosphatidylglycerol	Glycerol	$-CH_2-CH(OH)-CH_2-OH$	−1
Phosphatidylinositol 4,5-bisphosphate	*myo*-Inositol 4,5-bisphosphate		−4
Cardiolipin	Phosphatidyl-glycerol		−2

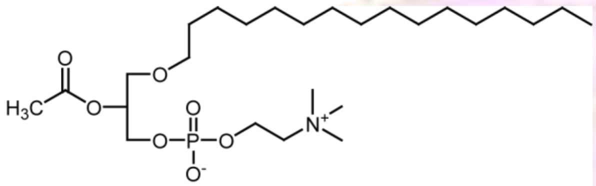
Table 1: Types of glycerophospholipids and their head groups

Source: http://physwiki.ucdavis.edu/@api/deki/files/1607/3.jpg?size=bestfit&height=480&revision=1

Some animal tissues and unicellular animals are rich in ether lipids, i.e. they have one of the two fatty acid joined in an ether linkage to glycerol rather than an ester linkage. Example of ether linked phospholipids are plasmalogen and platelet activating growth factor.



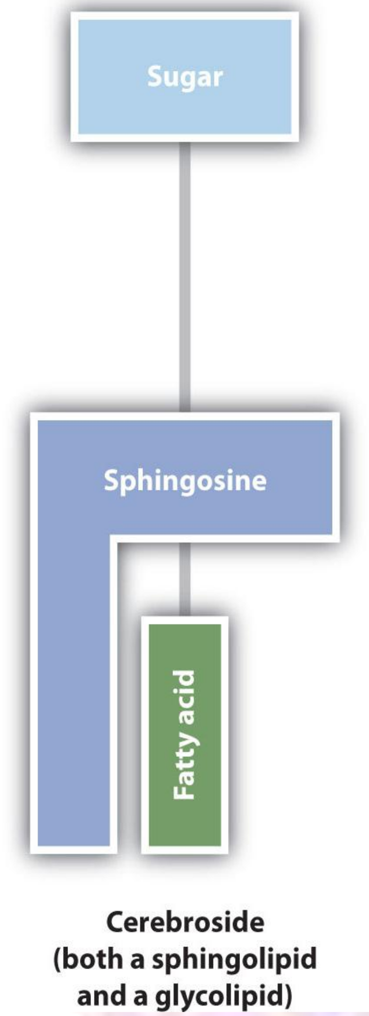
https://www.flickr.com/photos/50088088@N02/6155876923/



http://commons.wikimedia.org/wiki/File:PAF-platelet_activating_factor.png

2. Glycolipids

Glycolipids are the sugar containing lipids. These lack phosphate but have a simple or complex sugar.



Source: http://2012books.lardbucket.org/books/introduction-to-chemistry-general-organic-and-biological/s20-03-membranes-and-membrane-lipids.html (CC)

Galactolipids and Sulfolipids

Galactolipids are present in thylakoid membrane making almost 80% membrane lipids of higher plants. Therefore, they are the most abundant membrane lipids of the biosphere. In galactolipids one or two galactose residues are connected to C-3 of 1,2 diacylglycerol (DAG) by a glycosidic linkage. Sulfolipids are also present in plants they have a sulfonated glucose residue joined to 1,2 diacylglycerol by a glycosidic linkage. The sulphonate has a fixed negative charge just like that of phosphate group of phospholipids.

3.Sphingolipids: They are phospholipids derivatives of amino alcohol sphingosine. They have two non polar chains and a polar head group but no glycerol. They are composed of one molecule of long chain sphingosine or one of its derivatives, one fatty acyl chain and a polar head group joined by either phosphodiester or glycosidic linkages. Structurally C-1, C-2 and C-3 of sphingosine are similar to three carbons of glycerol moiety of glycerophospholipids as shown in the figure. In **ceramides** a fatty acyl chain is linked via an amide linkage at C-2 of sphinosine. All sphingolipids are derivatives of ceramides and classified into three categories: namely sphingomyelins, glycosphingolipids and gangliosides. **Sphingomyelins** have phosphocholine or phosphoethanoamine as their polar head groups. They are present in plasma membrane of animals and are especially abundant in myelin sheath that insulates neurons. **Glycospingolipids** have sugar residues attached to the C-1 of ceramide and have no phosphate. They are present on the outer surface of plasma membrane. They do not contain phosphate groups thus similar to galactolipids.

Cerebrosides have only one sugar attached to ceramides. Those containing Galactose are present mainly in neuronal cells and those with glucose are present in other cells. **Globosides** are glycospingolipds with two or more sugars. Globosides and cerebrosides are also known as neutral glycolipids as they are uncharged at neutral pH. **Gangliosides** are complex sphingolipids having oligosaccharides as their polar head groups and one or more residues of n-acetylneuramic acid (a sialic acid) at the termini. Sialic acid gives charge to them at neutal pH. Sphingolipids are sites of recognition among cells. Also certain carbohydrate moieties of these define blood groups of humans. Functions of gangliosides:

1. as surface markers for cellular recognition and cell to cell communications
2. Promote survival and regrowth of injured neurons.

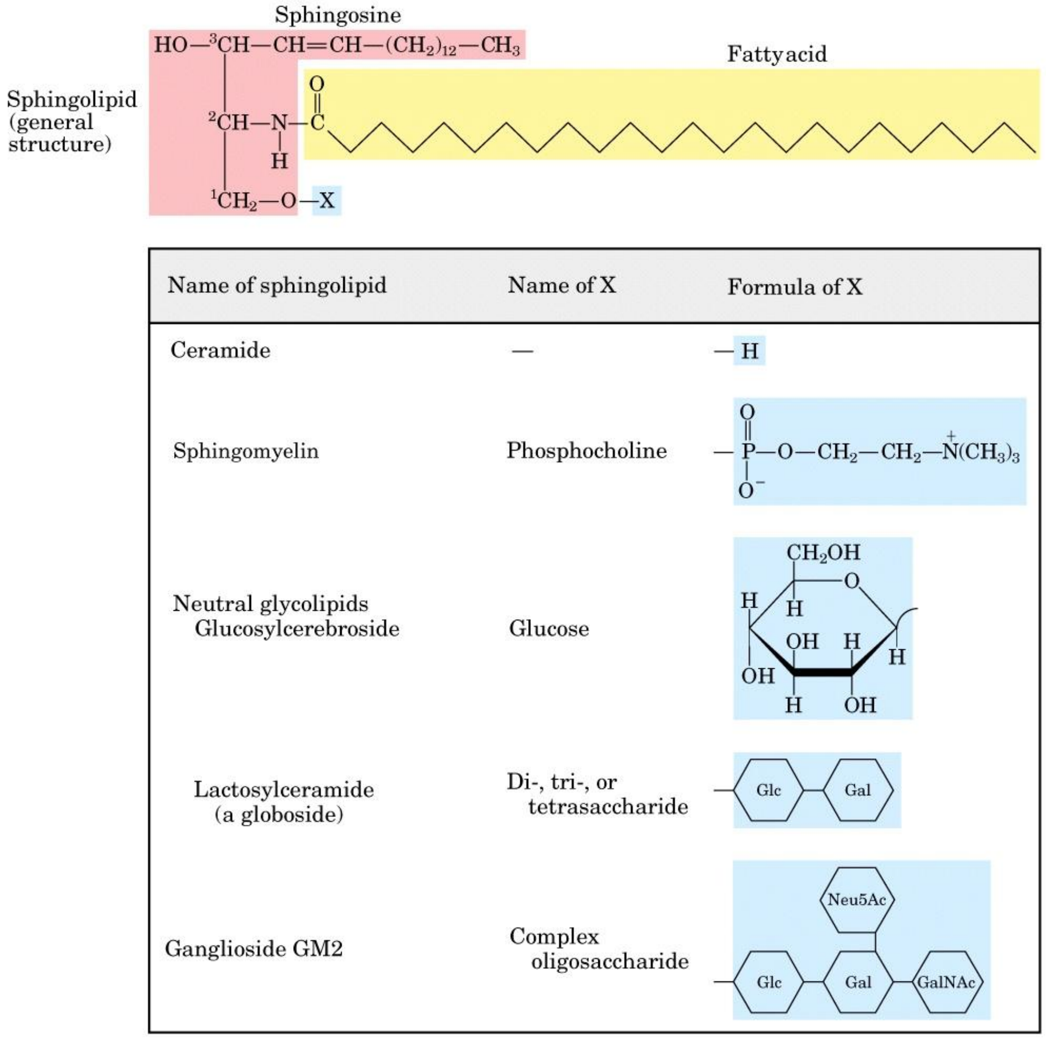
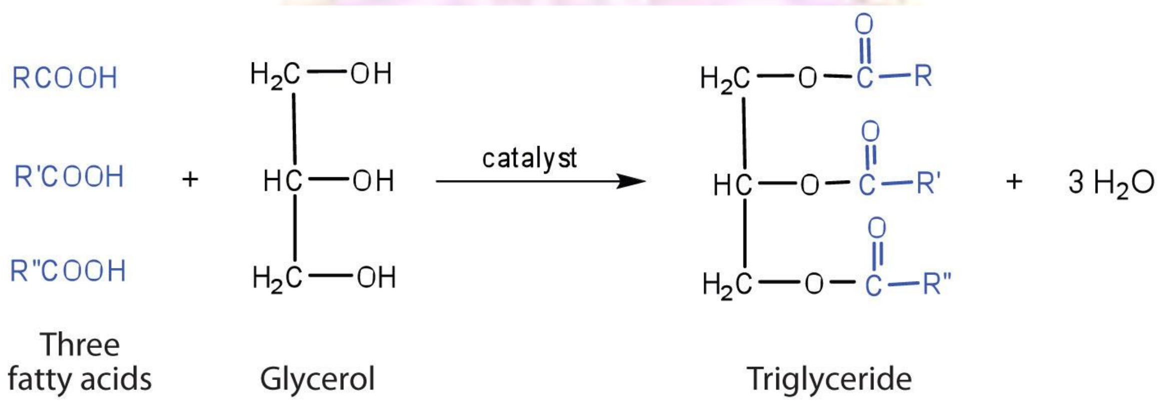


Figure: Sphingolipids

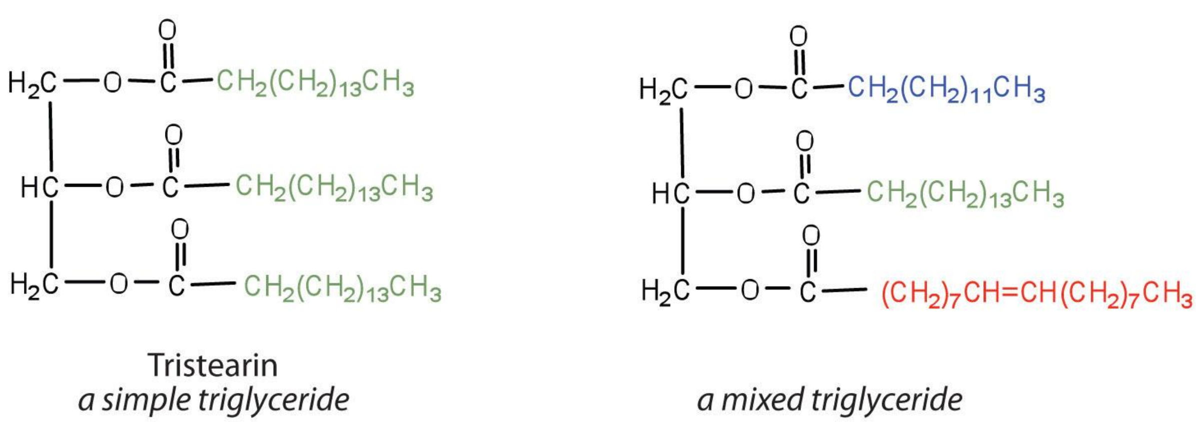
Source: http://physwiki.ucdavis.edu/@api/deki/files/1610/table.jpg?revision=1

Storage Lipids - Triacylglycerol

Triacylglycerol are the simplest form of lipids and are universal form of stored energy. They are also known as triglycerides or fats. Triacylglycerol are formed by esterification of three fatty acids with the three hydroxyl group of glycerol. Triacylglycerol having same fatty acids on all the three positions of glycerol are known as simple triglycerides and are named according to the fatty acid. For example: A triglyceride having stearic acid esterified to all the -OH group of glycerol will be known as tristearin, similarly oleic acid containing triglyceride will be known as triolein. Most naturally occurring triglycerides are mixed i.e. they have different fatty acids attached to the glycerol. They are named by specifying the position of each fatty acid .The properties of triacylglycerol depends upon the properties of their fatty acids. Triaacylglyerol having saturated fatty acids are solid at room temperature and are known as fats. Triacylglycerols having unsaturated fatty acids are liquid at room temperature and are known as oils. Fats are mostly found in animals while oils mostly occur in plants.



Source: http://2012books.lardbucket.org/books/introduction-to-chemistry-general-organic-and-biological/s20-02-fats-and-oils.html



Source: http://2012books.lardbucket.org/books/introduction-to-chemistry-general-organic-and-biological/s20-02-fats-and-oils.html

Functions of triacylglycerol

Triacylglycerol served as stored fuel in most of the eukaryotes. In animals they are present as fat droplets in specific cells. While many plants stores oil in their seeds which provide energy and biosynthetic precursors during seed germination. Triacylglycerols are the preferred choice than polysaccharide for storing metabolic energy because of two reasons. First oxidation of fats provides more energy as compared to polysaccharide because they are more reduced. Another advantage is that fats can be stored in anhydrous form therefore a large amount can be stored. In some animals such as seals, penguins and other warm blooded animals triacylglycerols serves as insulation against the low temperature. Hibernating animals (for e.g., Bear) store large amounts of fats before hibernation, which provides energy as well as insulation. Low density of triglycerides serves another purpose in sperm whales. In sperm whales, a store of triacylglycerols and waxes allows the animals to match the buoyancy of their bodies to that of their surroundings during deep dives in cold water.

Comparing Fats and Oils

The triesters of fatty acids with glycerol (1,2,3-trihydroxypropane) compose the class of lipids known as fats and oils. These **triglycerides** (or triacylglycerols) are found in both plants and animals, and compose one of the major food groups of our diet. **Triglycerides that are solid or semisolid at room temperature are classified as fats, and occur predominantly in animals. Those triglycerides that are liquid are called oils and originate chiefly in plants**, although triglycerides from fish are also largely oils. Some examples of the composition of triglycerides from various sources are given in the following table.

	Saturated Acids (%)					**Unsaturated Acids (%)**		
Source	**C_{10} & less**	**C_{12} lauric**	**C_{14} myristic**	**C_{16} palmitic**	**C_{18} stearic**	**C_{18} oleic**	**C_{18} linoleic**	**C_{18} unsaturated**
Animal Fats								
butter	15	2	11	30	9	27	4	1
lard	-	-	1	27	15	48	6	2
human	-	1	3	25	8	46	10	3

fat								
herring oil	-	-	7	12	1	2	20	52
Plant Oils								
coconut	-	50	18	8	2	6	1	-
corn	-	-	1	10	3	50	34	-
olive	-	-	-	7	2	85	5	-
palm	-	-	2	41	5	43	7	-
peanut	-	-	-	8	3	56	26	7
safflower	-	-	-	3	3	19	76	-

As might be expected from the properties of the fatty acids, fats have a predominance of saturated fatty acids, and oils are composed largely of unsaturated acids. Thus, the melting points of triglycerides reflect their composition, as shown by the following examples. Natural mixed triglycerides have somewhat lower melting points, the melting point of lard being near 30 º C, whereas olive oil melts near -6 º C. Since fats are valued over oils by some Northern European and North American populations, vegetable oils are extensively converted to solid triglycerides (e.g. Crisco) by partial hydrogenation of their unsaturated components. Some of the remaining double bonds are isomerized (to trans) in this operation. These saturated and trans-fatty acid glycerides in the diet have been linked to long-term health issues such as atherosclerosis.

Source:http://chemwiki.ucdavis.edu/Organic_Chemistry/Lipids/Fats_and_Oils

For further details on trans fatty acids as risk for cardiovascular disease visit:http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3955571/

DID YOU KNOW

- Pizza lipids are mostly triacylglycerols varying in fatty acid composition. Most abundant ones are oleic acid, stearic acid, palmitic acid, linolenic acid, myristic acid and a 18.2 fatty acids.They all have even number of carbon atoms as always two carbons are synthesized at a time. They are a mixture of saturated and unsaturated fatty acids.
- Vitamin E is a group of lipids called tocopherols which are antioxidants abundant in wheat germ, vegetable oils and eggs.

- Lipids play an important in human health issues. High cholesterol leads to cardiovascular diseases. It is also a cause for rheumatoid arthritis, asthma and Alzheimer's disease.
- As cholesterol is insoluble in blood, it is carried by carriers called lipoproteins to and from the cells.
- **HDL or High Density Lipoprotein** is a good cholesterol as high level of HDL prevents heart attack.
- **LDL OR Low Density Lipoprotein** is a bad cholesterol which gets accumulated on the walls of arteries supplying blood to heart and brain condition called **atherosclerosis** leading to heart attack.

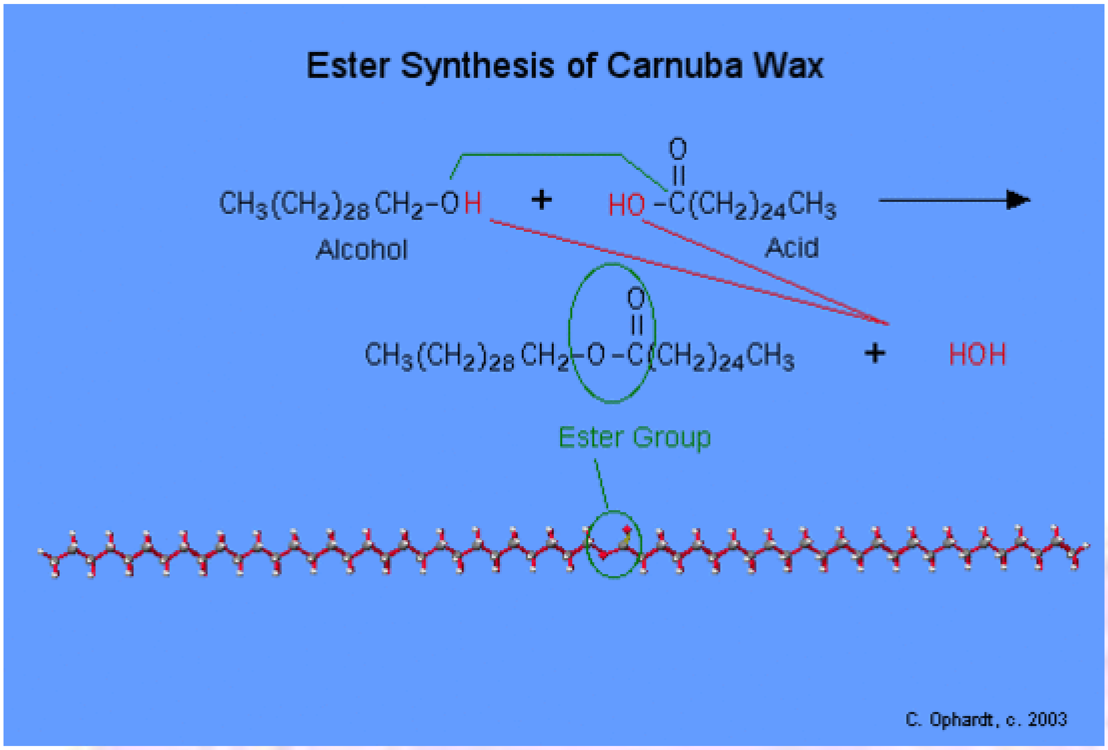
Waxes

Waxes are esters of long chain alcohols with long chain fatty acids. The resulting molecule has a weakly polar head group (the ester moiety) and a long, non-polar tail (the hydrocarbon chain). They usually have saturated fatty acids whereas the alcohols may be saturated or unsaturated and may include sterols, such as cholesterol. Waxes are water insoluble due to the weakly polar nature of the ester group. So this class of molecules has a water-repellant character to animal skin, to the leaves of plants and to bird feathers. They are synthesized by both plants and animals. The glossy surface of an apple is because of a waxy coating. The most important animal wax is beewax obtained from honey bees. **Carnauba wax** obtained from the palm tree *Copernicia prunifera* in Brazil, is a hard wax used for a gloss such as in automobile wax, floor wax and shoe polish.

Lanolin, a component of wool wax is used as a base for pharmaceutical and cosmetic products because it is rapidly assimilated by human skin.

Paraffin Waxes are mixtures of alkanes i.e. hydrocarbons in contrast to natural waxes which are esters derived from carboxylic acids and alcohols. They are used in foods like chewing gums, in candles, cosmetics and polishes.

Montan Wax is obtained from coal and lignite and is a fossilized wax which is very hard due to high concentration of saturated fatty acids and alcohols but not esters, characterizing softer waxes. Commercially useful products can be obtained from montan wax.



http://chemwiki.ucdavis.edu/Biological_Chemistry/Lipids/Non-glyceride_Lipids/Wax

Sterols

Sterols are derived from **cyclopentanoperhydrophenanthrene**, which has four fused and nonplanar rings. Three of these rings have six carbons. As the fused rings are rigid, they do not allow rotation around C-C bond. They belong to the class of structural lipids. Mostly they are present in the membranes of eukaryotic cells.

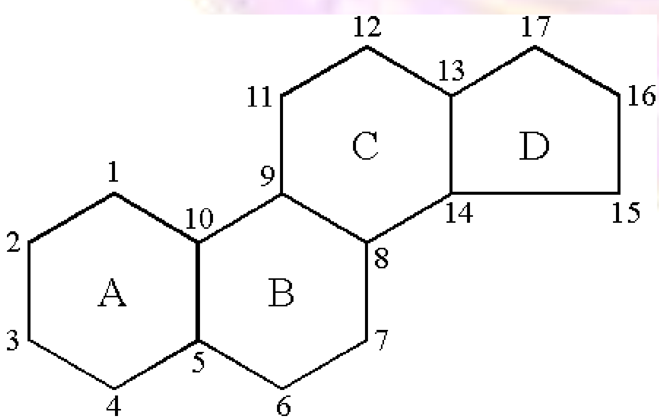
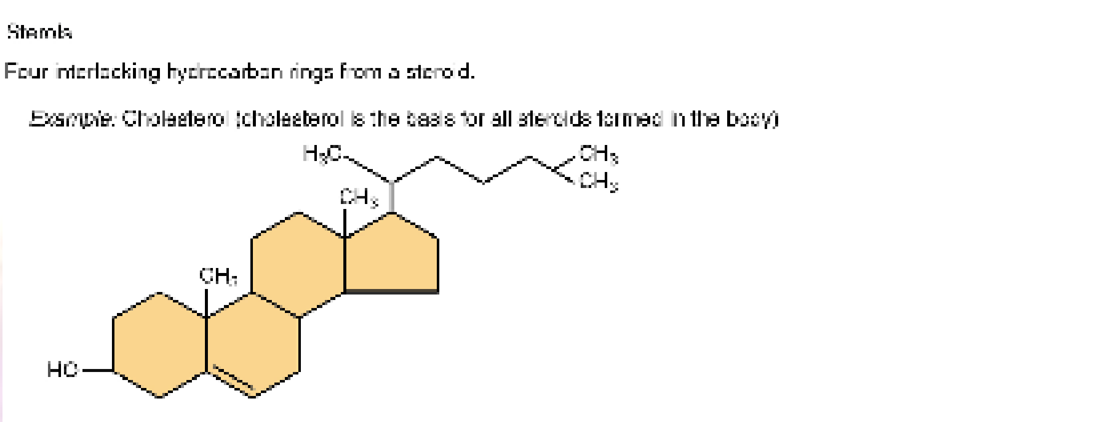


Figure:cyclopentanoperhydrophenanthrene

Source:http://patentimages.storage.googleapis.com/US6444660B1/US06444660-20020903-C00001.png

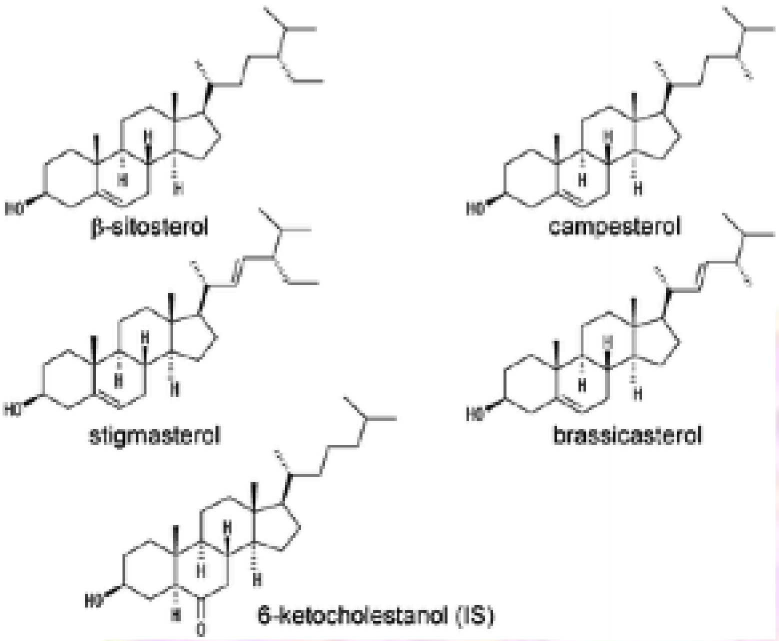
Cholesterol being a most common steroid in animals is studied in detail. It is a precursor of other animal steroids. It is amphipathic in nature having polar head and non-polar hydrocarbon chain. It is a main component of animal cell plasma membranes and is also found in membranes of other cell organelles in smaller amounts.



Cholesterol

Source:http://cnx.org/content/m46008/latest/?collection=col11540/latest

Plaques formed on arterial walls are also chiefly formed by cholesterol in **atherosclerosis**. It also forms lipoprotein complexes in the blood. The other eukaryotes also have similar sterols e.g. fungi have ergosterol and plants are rich in stigmasterol. Bacteria lack sterols but can incorporate sterols exogenously.



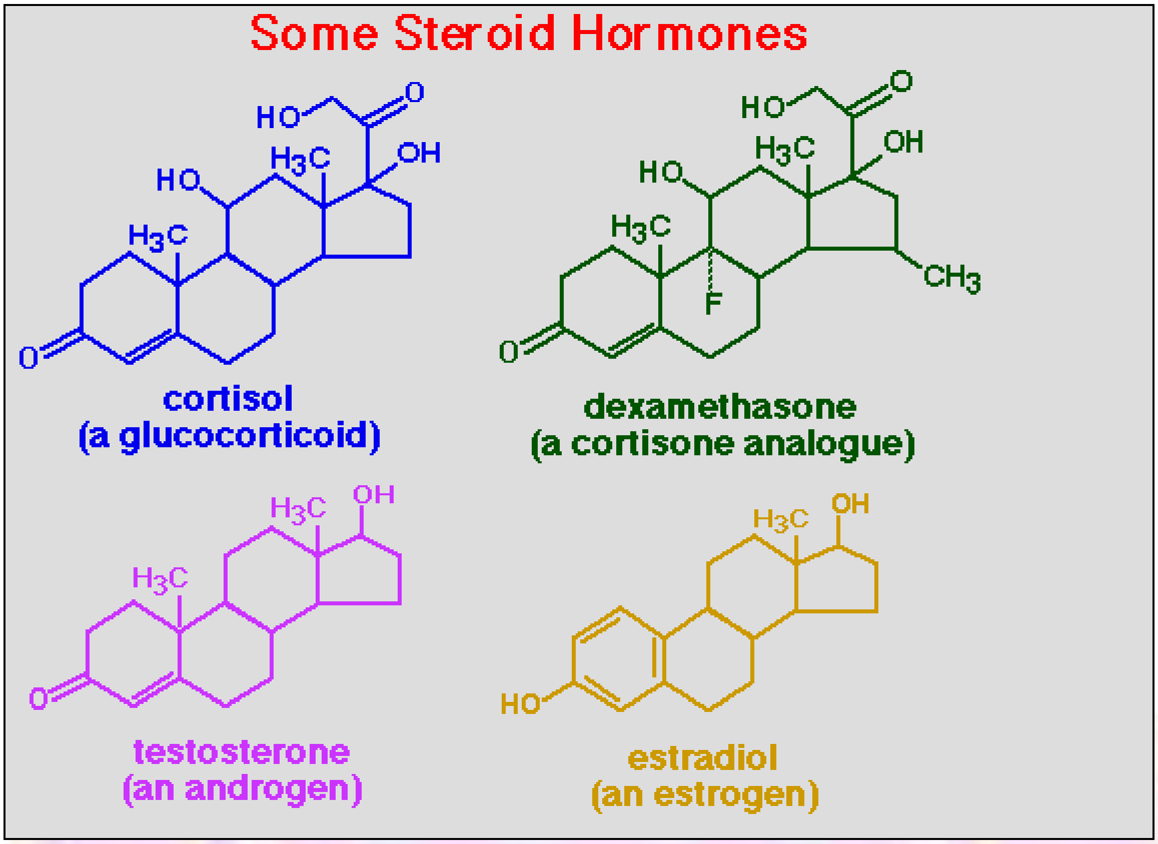
Plant sterols

http://pubs.rsc.org/en/content/articlelanding/2010/ay/b9ay00195f/unauth#!divAbstract

- **Plant sterols cannot be absorbed by the body. They also block the intestinal absorption of cholesterol effectively.**

In mammals, steroid hormones are derived from cholesterol. They have three classes.

1. **Glucocorticoids** e.g., Cortisol. They control carbohydrate, protein and lipid metabolism.
2. **Mineralocorticoids** e.g., Aldosterone regulate water and salt excretion by kidneys.
3. **Androgens** e.g. Testosterone and estrogens like β-estradiol control sexual development and functions in animals.
4. **Progestins** control the pregnancy and menstrual cycle.
5. **Bile acids** secreted by gall bladder help in the absorption of lipids in intestine.



http://universe-review.ca/F11-monocell04.htm

Summary

- Lipids are diverse group of molecules which are soluble in organic solvents.
- They do not form polymers unlike other biomolecules.
- Fatty acids are carboxylic acids which have variable chain lengths and degree of unsaturation.
- Triacylglycerols are esters of fatty acids and glycerols.
- Fats and oils are the principal stored forms of energy in most of the organisms whereas Phospholipids and sterols are the major structural elements of biological membranes.
- Lipids are classified as simple lipids and complex lipids. Fats and waxes belong to simple lipids whereas phospholipids and glycolipids belong to the complex lipids.

Glossary

Fats :Esters of fatty acids with glycerol.

Oils : fats in liquid state

Waxes : esters of long chain alcohols with long chain fatty acids.

Fatty Acids. A fatty acid is a carboxylic acid having a long hydrocarbon chain (tail) and a terminal carboxyl group (head).

Saturated Fatty acids have all carbon-carbon bonds are single bonds.

Unsaturated Fatty acids have one or more double bonds in the hydrocarbon chain.

Emulsification. It is a process of dispersing an oil in an emulsion.

Micelle. Molecules with bith polar and unpolar groups form aggregates in aqueous solution called micelles.

Triglycerides (TAGs) They are the esters of glycerol and three fatty acids.

Steroids. Organic compound containing an arrangement of four cycloalkane rings joined to each other in a characteristic way.

Exercises

Multiple choice type questions

1. Triacylglycerols are

a) Soluble in water

b) Insoluble in water

c) Soluble in water at at elevated temperature

d) Partially soluble in water

2. Phospholipids contain

a) Hydrophilic heads and hydrophobic tails

b) Long water soluble carbon chains

c) Positively charged functional groups

d) Both b and c

3. Micelles of fatty acids in water are organized such that the______ faces the solvent and the _____are directed towards the interior.

   a) Carboxylic acid groups, hydrocarbon chains heads

   b) Hydrophilic heads, hydrophobic tails

   c) Hydrocarbon chains, carboxylic acid groups

d) Both a and c

4. Which of the following is/are unsaturated fatty acids?
   a) Linoleic acid
   b) Palmitic acid
   c) oleic acid
   d) all above

5. Liquid form of triglycerides at room temperature are called
   a) Fats
   b) waxes
   c) Oils
   d) None of the above

True or false

1. Lipids are insoluble in water
2. Palmitic acid is an essential fatty acid.
3. Sterols are storage lipids present in membranes.
4. Sulpholipids contain sulphur and phosphorus in their structure.
5. Naturally occurring unsaturated fatty acids are all of *cis*configuration.

Subjective Questions

1. How are lipids different from the other three classes of biomolecules?
2. Does cis- oleic acid have a higher or lower melting point than trans- oleic acid. Explain.
3. Animals cannot synthesize linoleic acid a precursor of arachidonic acid and therefore must obtain this fatty acid from their diet. Explain why cultured animal cells can survive in the absence of linoleic acid.
4. Why can't triacylglycerols be significant components of lipid bilayer?
5. What is the biological importance of unsaturated fats?
6. What is the function of Omega-3 oils? Name a good source of omega -3 oils.

7. An individual has a diet rich in meats i.e. with high level of cholesterol and the other has a diet rich in plant sterols. How would you compare the two in terms of risks of cardiovascular diseases? Explain with reasons.

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